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DISTURBANCES OF ARTERIAL BLOOD SUPPLY TO THE SPINAL CORD AND BRAIN STEM CAUSED BY SPONDYLOSIS, DISC PROTRUSIONS AND ROOT-SLEEVE FIBROSIS

A concept concerning factors eliciting amyotrophic lateral sclerosis

By

TORE PATRICK STÖRTEBECKER, M. D.

Oslo, Norway

INTRODUCTION

The purpose of the present paper is to give some aspects on the influence of vascular factors in the pathogenesis of myelopathy.

The *lack of correlation* between the degree of spondylotic changes and both the severity of neurological symptoms and their segmental level has been pointed out by many authors[10, 11, 14, 17, 35], who have commented on the reason why only certain individuals with spondylosis develop myelopathy.

The importance both of a direct *mechanical* compression of the cord and of *vascular* factors has been discussed[7, 10, 14, 17, 27, 35, 41, 52].

An abstract of this paper was presented at the 14th annual meeting of the Scandinavian Society of Neurosurgery, Stockholm, Sept. 5th 1959. The matter of surgical intervention on cases of amyotrophic lateral sclerosis has twice been proposed at Staff-meetings, Sahlgrenska Sjukhuset, Göteborg, March 8th 1958 and April 16th 1959.

The picture of *amyotrophic lateral sclerosis* is characterized by symptoms of slowly progressive wasting of the muscles, especially those innervated from the cervical cord and the medulla, and of pyramidal tract lesions. The symptoms of either central or peripheral motor neurone lesions may dominate giving different clinical varieties depending on the localisation of the lesions.

Many authors have touched upon the problem that neurological symptoms seen in cases of spondylosis and disc protrusions may simulate the picture of amyotrophic lateral sclerosis. But mostly they warn against making an erroneous diagnosis[2, 3, 11, 12, 17] instead of connecting their observations with the symptoms of amyotrophic lateral sclerosis and its pathogenesis.

Thus i. a. BUCY and coworkers[12] (1948) stressed that the possibility of confusing a herniated cervical intervertebral disc with amyotrophic lateral sclerosis is a serious matter. They reported a very interesting case earlier diagnosed as amyotrophic lateral sclerosis which at surgical intervention revealed a cervical neurinoma (C_{4-5}). They remarked that the bulbar symptoms with increased jaw reflex was difficult to explain; however, they did not correlate their interesting observation to the pathogenesis of amyotrophic lateral sclerosis.

An interesting fact is that almost 20 years ago surgical exploration was made by TEMPLE FAY[16] (1942) who published a report of high cervical laminectomy in 4 cases of amyotrophic lateral sclerosis.

GREENWOOD[19] (1942) contributed to the following discussion and commented with regard to amyotrophic lateral sclerosis that if we have a *chronic anoxemia of the cord*, whether it be due to a slowly developing tumor or a direct reduction of circulation such as occurs in anterior artery thrombosis, the motor tracts are the first to suffer, whether they be upper motor or lower motor.

This view of TEMPLE FAY[16] and GREENWOOD[19] was met with almost unbelievable opposition and negativism from orthodox neurologists who held the opinion that amyotrophic lateral sclerosis was a systemic disease which is inherent in the neural tissue itself and seemed rather annoyed, too, that "this struggle in regard to the proper appreciation of amyotrophic lateral sclerosis as a disease *sui generis* seems to have no end" (ALSOP RILEY[44] 1942).

So this remarkable trial, almost 20 years ago, to treat these hopeless cases of amyotrophic lateral sclerosis by surgical intervention seems to have fallen into oblivion.

In the following I would like to give a few comments on some clinical and experimental conditions caused by a local deficiency of blood supply to the spinal cord and brain stem.

CASE REPORTS

To illustrate the importance of an adequate arterial blood supply to the cervical region of the spinal cord an exemplifying case will be described.

In 1952 the following case, which I saw at Serafimerlasarettet in Stockholm, convinced me that the spinal symptoms in the picture of amyotrophic lateral sclerosis could be induced by lack of *radicular* arterial blood supply to the spinal cord.

Case 96—06—08. H. D., Neurol. dept., Serafimerlasarettet, 1952.

A 55-year-old Norwegian baker with a case history of about 1 year. Since Dec. 1950 he had observed progressive weakness of his left arm-hand and since April 1951 limping and weakness of his left leg. No sensory or sphincter disturbances.

At examination in Jan. 1952. Muscular atrophy of the left shoulder girdle and left upper extremity, highly pronounced in the left hand. Slight muscular atrophy of the left thigh and leg, with impaired dorsal extension of the left foot. Fasciculations corresponding to the regions of muscular atrophy. The muscle reflexes were generally decreased and the left biceps reflex was absent. Babinski sign absent. Masseter reflex was increased but else no bulbar symptoms. No sensory loss.

Spinal fluid: increased total protein to 103 mg % in the lumbar sample and 70 mg % cisternally. No pleocytosis. WR neg. *Duplography:* free communication by Queckenstedt test.

EMG in the left arm-hand showed lesions of the peripheral motor neurones. *Muscle biopsy*, left triceps: neurogenic atrophy.

Roentgenological examination showed disc degenerations in the *cervical* region, especially C_{5-6}, with *large osteophytes* protruding into the adjacent *intervertebral foramen*, highly narrowing it on the *left* side.

In the thoraco-lumbar region there were moderate spondylotic changes, but without any significant disc degenerations on the roentgenograms.

Air-myelography showed a slight protrusion of the degenerated disc C_{5-6}, but else no deformation of the subarachnoidal space.

The patient was transmitted to the Neurosurgical dept., Serafimerlasarettet, for operation under the diagnosis of suspected cervical root-sleeve fibrosis.

Operation Feb. 1st 1952 (Dr. RAGNAR FRYKHOLM*): Hemifacetectomy C_{5-6} + Radiculolysis. The surgical intervention revealed a most interesting operative field when at the stage of splitting of the cervical root-sleeve fibrosis (C_{5-6} sin.) the adjacent *radicular artery* appeared *totally compressed* and blood-less. More laterally the artery widened, but *corresponding to its passage through the intervertebral foramen*, surrounded by the root-sleeve fibrosis, *this radicular artery was obliterated.*

Postoperatively the course showed a steady progression of his muscular disability with increasing paresis of his both arms and legs, most pronounced on the left side. He was almost bedridden his last year until he died of a bronchopneumonia in Dec. 1953 at Drammen Hospital, Norway, about 3 years after onset of the symptoms.

Comment. With regard to the *diagnosis* in this case it was labelled as amyotrophic lateral sclerosis at the Neurol.dept. of Drammen Hospital, Norway, in August 1951 (5 months before operation). In Jan. 1952 when I examined the patient at the Neurol.dept., Serafimerlasarettet, Stockholm, the case fulfilled the clinical criteria of progressive spinal muscular atrophy. In Dec. 1953 some days before the patient died at Drammen Hospital, Norway, the diagnosis was amyotrophic lateral sclerosis.

At the Neurosurgical dept., Serafimerlasarettet in Feb. 1952 the differential diagnosis was put between either a myelopathy caused by circulatory disturbances in the anterior horns of the spinal cord or amyotrophic lateral sclerosis.

The logical conclusion of the finding at surgery that the obliteration of the radicular artery should be directly connected with the pathogenesis of amyotrophic lateral sclerosis, was not accepted at that time.

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*) I wish to express my best thanks to Dr. Ragnar Frykholm for permission to report his neurosurgical intervention on this case.

The *next case* is representative of the *Aran-Duchenne* type of *amyotrophic lateral sclerosis.* It might give some viewpoints on the pathogenetic role of cervical spondylosis connected with highly constricted intervertebral foramina in this region.

Case 08—02—20. T. L., Neurol. Clinic, Sahlgrenska Sjukhuset, 1955—1959.

A 51-year-old stevedore with a case history of about 5 years. In 1954 he observed weakness of his *right* hand-arm and in the following years a steadily progressive weakness of both hands, arms and shoulder girdles has developed. He is unable to use his arms and hands, he cannot put on his clothes, etc.

The lower extremities, on the contrary, are in good condition and the patient can walk about three miles without fatigue. The last two years he has observed a slight difficulty in swallowing and of speech. No sensory symptoms. No sphincter disturbances.

Examination (April 1959) showed highly advanced muscular atrophy localized to the upper extremities (see fig. 1.). Hardly any musculature was left bilaterally in the shoulder regions, arms and hands. The patient was unable to elevate his arms (see fig. 1. C), flex and stretch in the elbows, and there was no strength of finger-movements. There were signs of bulbar paralysis with atrophy of the tongue and facial musculature, especially on the lower parts of the cheek. Fasciculations were frequent in the affected areas. In enourmous contrast to the upper extremities was the musculature of the lower extremities which was rather good and showed only slight signs of atrophy and sparse fasciculations. All movements in the legs were of good strength, without any obvious paresis. There were no signs of sensory impairment. The muscle reflexes were almost abolished in the arms and rather lively in the legs. The Babinski sign was absent.

EMG in the upper extremities showed lesions of peripheral motor neurones. *Muscle biopsy* confirmed the neurogenic atrophy. *Spinal fluid* was normal and WR neg.

Roentgenological examination of the spinal column in *Aug. 1955* showed cervical disc degeneration at C_{4-5}, C_{5-6} and C_{6-7} with osteophytes and narrowing of the intervertebral foramina, especially on the *right* side at C_{5-6} and C_{6-7} (see fig. 2.).

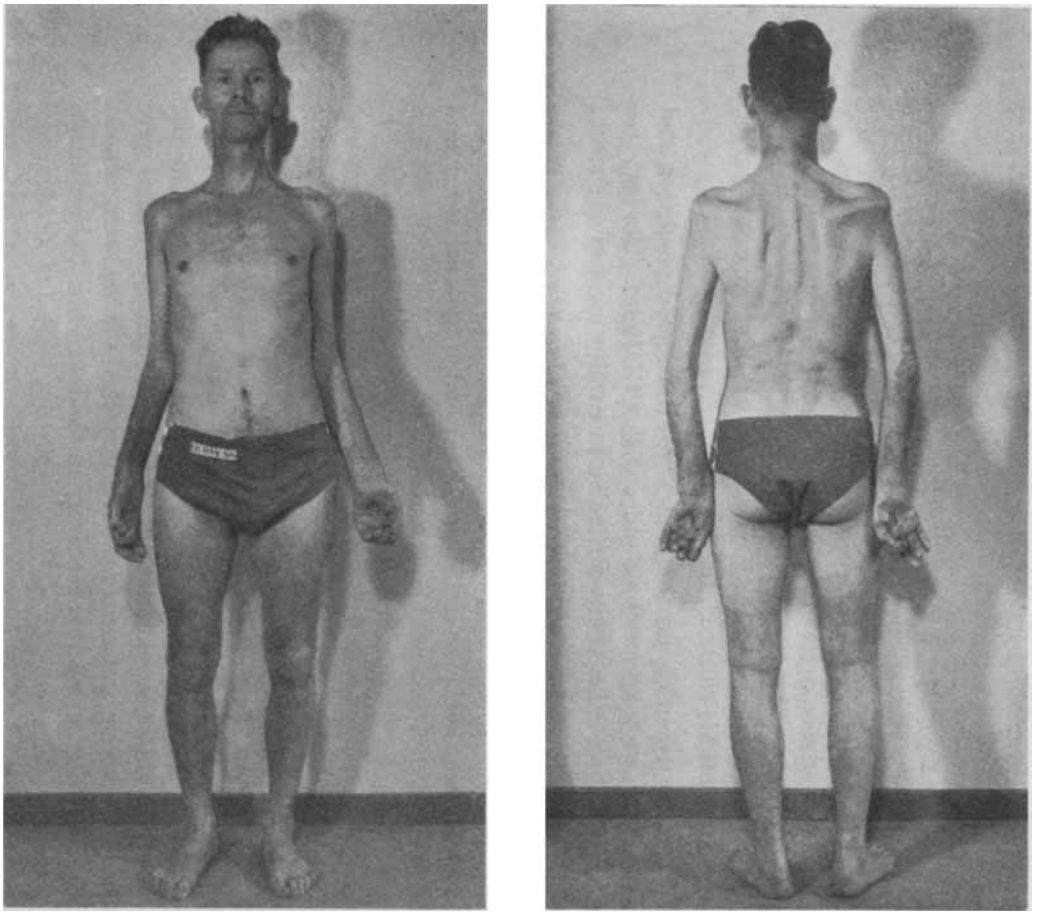
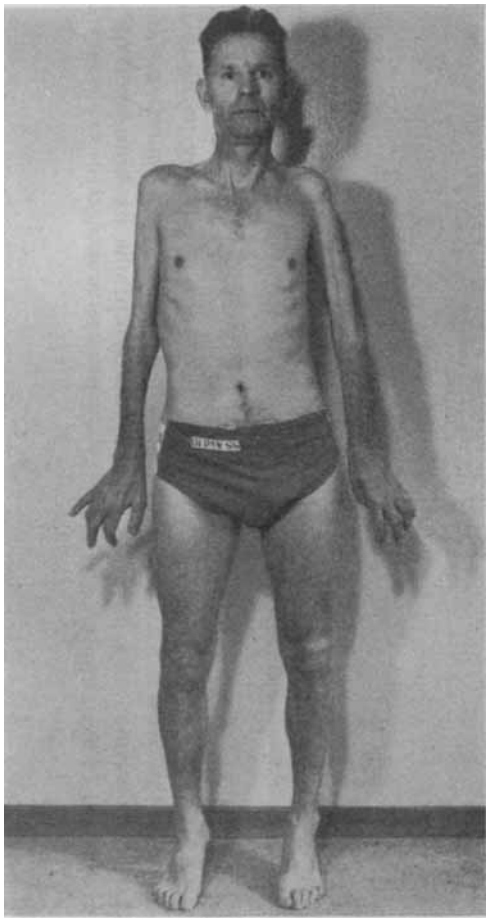


Fig. 1 A and B. Case 08—02—20. A 51-year old man with a 5-year case history of progressive wasting of the musculature starting in 1954 in the *right hand-arm* and developing into immense muscular atrophy of both upper extremities. Tongue atrophy and moderate bulbar paresis. The lower extremity musculature of good strength. No sensory symptoms. (The photographs taken in April 1959).



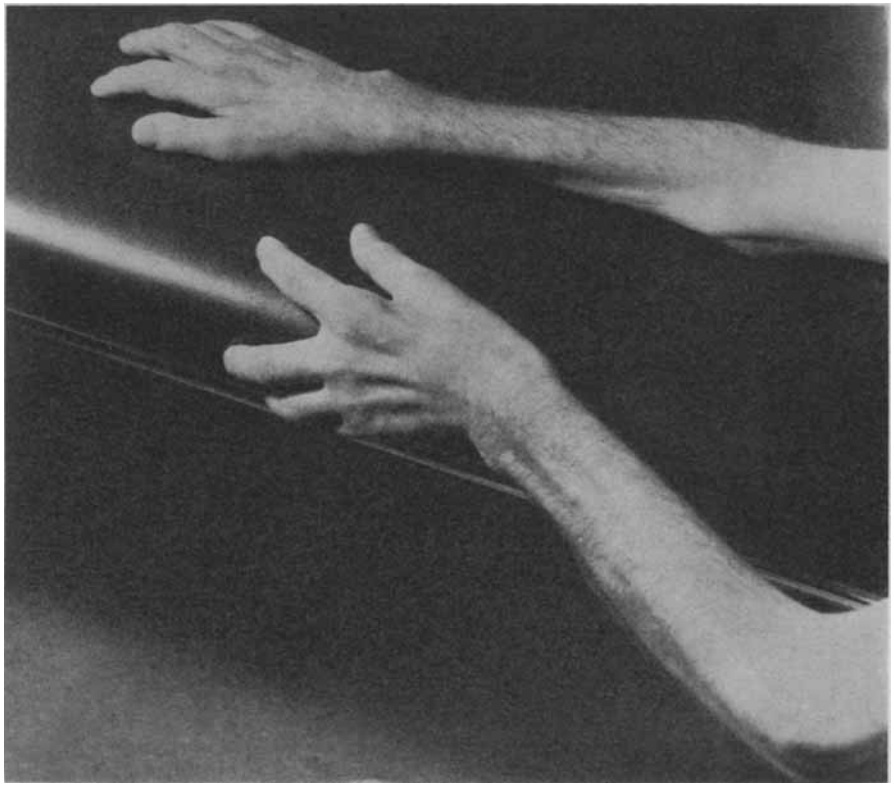


Fig. 1 C and D. Case 08—02—20. Note the striking contrast between the highly atrophic upper extremities and the powerful lower extremities when the patient is standing on his toes and tries to elevate his arms.

Roentgenological control in Feb. 1958 showed progress with regard to the narrowing of the C_{5-6} and C_{6-7} intervertebral foramina.

In the lumbar region disc degenerations with rather large osteophytes on the edges of the vertebral body joints were seen. Though the *intervertebral foramina* in both the *thoracic* and *lumbar* regions were without pathologic changes on the roentgenograms (this in contrast to the finding of some highly constricted intervertebral foramina in the *cervical* region).

Air-myelography in Jan. 1957 showed protrusion of cervical discs especially in the region C_{4-5}, but the protrusion did not reach in contact with the spinal cord, neither in extension nor flexion-posture of the neck.

Comment. If, according to the orthodox neurological nomenclature, we classify this case as the Aran-Duchenne type of amyotrophic lateral sclerosis, we only have to await its inevitable fatal progress.

If, instead, we put the question how these local lesions of the cervical cord and of the brain stem might develop, it is of primary importance to understand the pathogenesis and nature of the lesions and analyse the possible role of disturbances of the local blood supply to the affected regions.

In this connection I would like to draw attention to some pathological conditions induced by lack of arterial blood supply to the spinal cord.

DISCUSSION

According to Poiseuille's law a reduction of the diameter of a vessel to 1/2 corresponds to a reduction of the flow in it to approximately 1/8. Thus narrowing of the diameter of an artery to 1/3 of its original size gives a decrease to about 1/27 of the normal blood flow in that artery.

Experimental work concerning hindrance of arterial blood supply to the spinal cord and effect of hypoxia

Since the Danish anatomist STENO[47] (1638—1686) made his classic experiment, compression of the aorta in a rabbit producing paralysis of the hind limbs, several authors have reported on its mechanism and experimentally induced neurological symptoms by hindrance of arterial blood supply to the spinal cord[15, 21, 29, 30, 31, 51, 53].

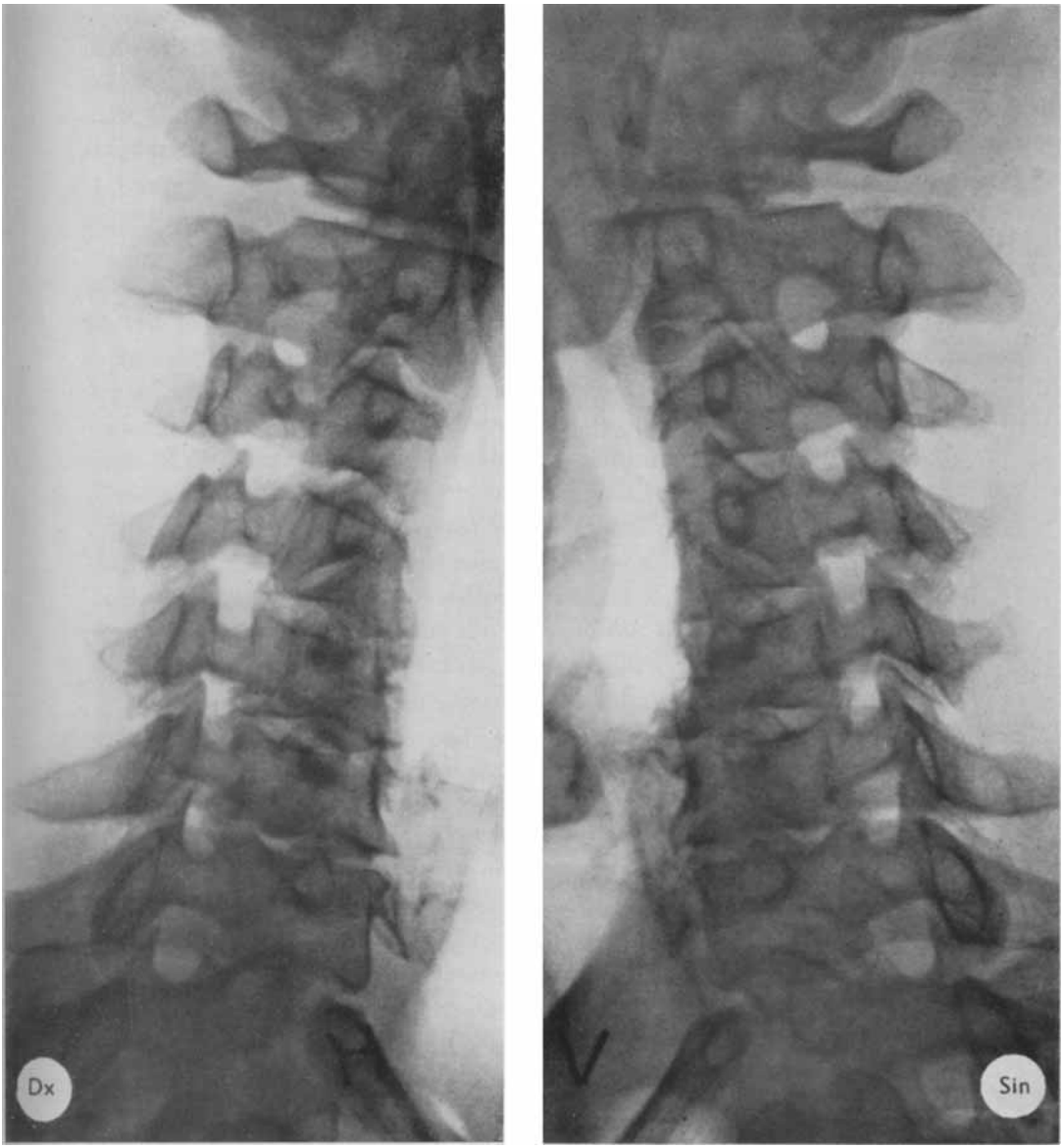


Fig. 2. Case 08—02—20. Roentgenological examination in 1955 of the cervical spine showed disc degenerations and narrowing of the intervertebral foramina C_{5-6} and C_{6-7}, most pronounced on the *right* side (corresponding to same-sided localisation of the initial paresis that started in the *right* hand and arm).

In these constricted intervertebral foramina the adjacent radicular arteries will be strangulated which induces a chronic deficiency of arterial blood supply to the cervical segments of the spinal cord with local involvement of the appropriate peripheral motor neurones.

According i. a. to STENO's compatriot the physiologist ERIK KROGH[30, 31], who studied the effect of acute hypoxia on the motor cells of the spinal cord, the damage to the cord depends on the duration of the period during which the aorta is compressed and on the degree of hypoxia.

Using radioactive isotopes KROGH[29] showed that during compression of the aorta an extremely slow circulation takes place in the affected part of the spinal cord requiring 1 hour or more for complete exchange of the blood in the capillaries. Normally this exchange takes place in much less than 1 minute.

In rabbits the spinal cord can withstand ischemia (aorta compressed by an abdominal clamp) for 10 to 15 minutes. After 20 minutes of ischemia the nerve cells are permanently injured and the large motor cells of the anterior horns are the most injured ones (HÄGGQVIST[21], KROGH[30, 31], TUREEN[51]).

By varying the experimental conditions with regard both to the degree and to the duration of compression of the aorta the mentioned authors were able to get all different stages of lesions, varying from slight microscopic changes of the large motor cells to heavy necrosis of the spinal cord with resulting paraplegia.

This is in accordance with the fundamental experiments by MORRISON[38] (1946) on the effect of repeated oxygen deprivation on the central nervous system. He showed i. a. that intermittent daily exposures of 3 to 4 hours of moderate artificial hypoxia administered for some months could induce lesions of grey matter as well as demyelination of white matter, with only slight pathologic changes of the vessels.

Thus by experimental work in animals it is possible to produce a combination of peripheral and central motor neurone lesions, a picture similar to the pathologic changes found in cases of amyotrophic lateral sclerosis.

It is, however, peculiar to note that hardly anybody seems to connect the above mentioned observations with the pathogenesis of amyotrophic lateral sclerosis. Still the hypothesis of an endogenous mechanism, a metabolic defect or a deficiency of some yet undetected metabolite responsible for amyotrophic lateral sclerosis is claimed, i. a. by KURLAND[32] (1957).

Anatomical considerations on the arterial blood supply to the spinal cord and brain stem

Investigators, contributing to the anatomy of the arterial blood supply to the spinal cord and brain stem, always point to its great individual variations in man[18, 22, 33, 34, 41, 42, 46, 49].

In the cervical region the *radicular* arterial blood supply is often maintained by one or two larger arteries passing through varying intervertebral foramina, either on the right or left side.

Thus, in human beings, it is difficult to predict anything about where the largest cervical radicular artery passes, especially as roentgenological examination of the radicular and spinal arteries using contrast medium seems to be highly injurious[23, 36].

Consequently the common roentgenological finding of spondylosis and a narrowed intervertebral foramen does not tell us if this narrowing really exerts a compression of one of the larger radicular arteries.

Another difficulty in evaluating the clinical picture is that in many cases root-sleeve fibrosis is observed in the absence of any obvious roentgenological constriction of the corresponding foramen (FRYKHOLM 1951)[17].

Pathological and clinical aspects on the arterial blood supply to the spinal cord and brain stem

It is beyond the scope of this paper to review all the numerous observations with regard to neurological manifestations of cervical spondylosis and herniated discs.

A *discongruence* between, on the one hand, the degree of spondylotic changes and, on the other hand, both the severity of neurological symptoms and their segmental level has been pointed out and many authors[10, 11, 14, 17, 35] have commented on the reason why only certain individuals with cervical spondylosis develop myelopathy.

The importance both of a direct *mechanical* compression of the cord and of *vascular* factors has been discussed by several authors[7, 10, 14, 17, 27, 35, 41, 52].

KAHN[27] (1947) claimed a *direct mechanical* cause of the neurological symptoms and stressed the role of the dentate ligaments in spinal cord compression and a syndrome of lateral sclerosis.

BUCY and coworkers[12] (1948) i. a. supported the view that KAHN's mechanical explanation of the development of the symptoms is more applicable than is the vascular one.

Observations on *vascular factors* in disturbing the functions of the spinal cord mostly concern cases with *acute* or *subacute occlusion* of spinal arteries. Thus ORNSTEEN[39] (1931) commented on 2 acute and subacute cases of thrombosis of the *anterior spinal artery* that "occlusion of the cervical anteromedian spinal artery produces a symptom complex of amyotrophic lateral sclerosis with dissociation of sensation of the spinal type, more or less irregular in its distribution."

Lesions within the cord in cervical myelopathy have been considered to result from compression of the *anterior spinal artery* and its branches by protruded discs (i. a. TUREEN[52] 1938, MAIR and DRUCKMAN[35] 1953).

With regard to the role played by *narrowing of the intervertebral foramina* i. a. BRAIN, NORTHFIELD and WILKINSON[11] (1952) observed that there could be a marked flattening of the nerve roots without any histological abnormality. They stress the *operative treatment* of enlarging and widely *opening all constricted foramina.* MAIR and DRUCKMAN[35] (1953) mentioned that "the role played by the narrowing of the intervertebral foramina in the pathogenesis in the cases described appears to be small." The mentioned authors, however, did not especially comment on the radicular arteries.

LAZORTHES and coworkers[33, 34] (1957/58) stress the importance of the *radicular arteries* and disturbances of their functions in the pathogenesis of different myelopathies, especially in the *lumbar* region where the bulk of the blood supply is furnished by one great lumbar radicular artery. They mention that in cases of *cervical* arthrosis compression of the vertebral artery and its *radicular* branches may induce medullary ischemia and lesions of the syringomyelic type. Similar pictures due to a deficiency of arterial blood supply to certain regions of the spinal cord have been reported i. a. by ZÜLCH[54] (1954).

Recently PAYNE[40] (1959) in a paper "the cervical spine and spondylosis" wrote i. a. that "there is evidence that the constricted foramina can produce a *radiculopathy* (CAVE et al.[13] 1955)". He[40] seems to favour the opinion of a direct mechanical compression in commenting that "the mode of production of the neurological disturbance is unknown although direct neuronal damage by compression is the most likely causal factor. The appearance of traumatic oedema would increase the severity of the constriction."

PAYNE[40] (1959) further commented: "Compression and obliteration of the *vessels* traversing the constricted foramina has never been demonstrated although it probably occurs. Occlusion of these vessels may well affect the blood supply of the spinal cord especially when the radicular arteries are few in number."

What concerns *direct mechanical factors* BRADSHAW[9] (1957) is somewhat more reticent in stating: "It is not possible to come to any definite conclusion with regard to the *pathogenesis of myelopathy* in cervical spondylosis. All that can be said with certainty is that evidence of compression is frequently lacking at operation, and there does not seem to be any tension upon the dentate ligaments, nor are adhesions seen to constrict or bring pressure to bear upon the spinal cord."

With regard to *vascular factors* BRADSHAW[9] further says that "SUH and ALEXANDER[49] (1939) have reminded us that the blood-supply of the cervical cord is derived from two, or at most three, unpaired radicular arteries, the remainder being too small to make any significant contribution. Thus, *if* one of these vessels was compressed in the appropriate foramen by osteophytes or by adhesions associated with root-sleeve fibrosis, between *one-half* and *one-third* of the blood supply to the cervical cord might be imperilled. If this contention were true it would explain the *discrepancy* between the radiological and clinical findings so often found, for the nature of the neurological deficit would then depend on whether or not a major radicular artery were compressed."

With regard to the circulation through the *vertebral arteries* both numerous anatomical studies and clinico-pathological observations of many different syndromes due to the tortuosity and compression of these arteries have been reported[20, 24, 28, 43, 50].

Thus i. a. HADLEY[20] (1958) commented that the vertebral arteries may be deflected and distorted by extrinsic pressure of bony spurs at the covertebral or apophyseal joints and that the decreased blood flow may be a factor in producing neurologic symptoms.

However, the symptoms of slowly progressive partial compression of the *vertebral artery* by disc protrusions and osteophytes do hardly seem to have been correlated to the pathogenesis of progressive bulbar paralysis.

Traumatic factors in the pathogenesis of amyotrophic lateral sclerosis

In a review of the amyotrophic lateral sclerosis syndrome and trauma JELLIFFE[26] (1935) remarked that the *original conception* that fashioned CHARCOT's disease as an *"abiatrophy" was consistent with neurological thinking at the time,* but more recent observations began to break down the disease entity idea and the clinical picture began to be seen as a resultant of a number of etiological factors.

With regard to the *traumatic factor* JELLIFFE[26] (1935) gathered about 90 earlier reported cases in which progressive muscular atrophy of typical course followed upon an injury and *commenced first in the region of the injury*. In the cases reviewed by JELLIFFE[26] the most common type of injury was that the patient slipped, and as he fell he caught himself by the one hand, so that his arm was violently stretched.

Traffic accidents, especially by car driving, with trauma against the neck and shoulder region followed by a typical picture of *cervical* progressive muscular atrophy and bulbar paralysis have recently been studied, i. a. by FRENCH authors[8] (1958).

None of the authors, however, gave any explanation of the possible *pathogenetic mechanism* responsible for the clinical picture.

With regard to *traction injuries* produced by trauma to the shoulder or arm which results in sudden forceful dislocation of the shoulder girdle FRYKHOLM[17] (1951) commented the following:

"Usually a traction injury results only in the stretching of the periradicular sheaths. These, however, contain wide, thin-walled vessels which are intimately adherant to the radicular nerves.

The rupture of a vessel results in local effusion and edema. This in turn induces fibrosis. The development of periradicular and root-sleeve fibrosis after traction injuries might thus be explained. Especially susceptible to such lesions are nerves which, due to cervical spondylosis, pass through constricted foramina. In such foramina there is little or no space to spare and even slight edema will tend to produce symptoms of root compressions."

In this connection I would like to mention that a repeated injury of the cervical spine in boxing, wrestling and similar sports ought to be considered as an etiological factor. Of pathogenetic interest with regard to a varying incidence of cervical myelopathy may also be the *chronic traumatic lesion* of the cervical spine *caused by axial compression*, due to the habit of carrying heavy burdens on the top of the head.

The effect of injury to the radicular arteries and the subsequent pathologic changes of the spinal cord caused by ischemia due to lack of radicular arterial blood supply seems hardly to have been commented upon in literature as a factor in the pathogenesis of traumatic cases of amyotrophic lateral sclerosis.

ANTONI and LINDGREN[1] (1949) reported a unique case from Serafimerlasarettet, Stockholm, of "Steno's experiment in man", *acute paraplegia* caused by aortography. The post-mortem examination with histological studies revealed the interesting fact that the *anterior roots* showed total denervation, while the posterior roots were rather well preserved. These authors[1] made an excellent review of earlier literature and gave an interesting discussion concerning *acute* neurological symptoms produced by hindrance of the arterial blood supply to the spinal cord. However, they did not give any comments on possible pathogenetic factors in *chronic* cases of spinal muscular atrophy.

Infectious-toxic factors eliciting spinal joint changes and narrowing of the intervertebral foramina

Several eliciting factors must be taken into account with regard to the pathogenetic mechanisms responsible for spondylosis, spinal joint changes and root-sleeve fibrosis.

The influence of a *traumatic* factor has already been discussed in this paper.

With regard to the role of an *infectious-toxic* factor in eliciting spondylosis and spinal joint changes the problem is still open to debate.

It might be of interest to consider a most fascinating study on medieval Danish skeletons with regard to tooth infection and spinal joint diseases published by MÖLLER-CHRISTENSEN and BRINCH[37] (1948). They classified the skeletons in two main groups: one without, the other with manifest dental infectious foci. They[37] found that a positive causal relationship existed between *dental infection* and certain osseous abnormalities in the cervical spine (MORBUS AEBELHOLT).

INGELMARK, MÖLLER-CHRISTENSEN and BRINCH[25] (1959) further elaborated this material of more than 200 medieval skeletons and stated that in the skeleton groups with dental infections both the vertebral body surfaces and the small vertebral joints were more frequently affected than in the groups without dental infection.

With regard to the *degree or intensity* of the spinal joint lesions INGELMARK[25] found that dental infection showed a strong positive correlation with the *degree* of *small vertebral joint lesions*, but no such relationship could be demonstrated with regard to the vertebral body joints.

INGELMARK[25] (1959) discusses the present attitude to the etiology of osteoarthritis and he stresses that the changes on the surfaces of the vertebral bodies should be interpreted as signs of intervertebral disc degeneration, whilst the changes in the *small vertebral joints* are *osteoarthritic* in character.

The importance of the *vertebral venous system* as a pathway for spread of possible infection or neoplastic cells was re-discovered by BATSON[4, 5] (1940). Its role i. a. in the pathogenesis of pelveo-*spondylitis* has been stressed by ROMANUS[45] (1953).

The *cephalic* and *vertebral venous system* as a route for *spread of bacterial products* in the pathogenesis of disseminated encephalomyleopathy has recently been reviewed by the present author (STÖRTEBECKER[48] 1959/1960).

It is interesting to note that almost 20 years ago TEMPLE FAY[16] and GREENWOOD[19] discussed the *matter of infection* of the internal vertebral venous plexus in their cases of myelopathy and amyotrophic lateral sclerosis.

GREENWOOD[19] (1942) mentioned i. a. that "many of these cases have had in addition true arthritis, lending to the idea that some of them are due certainly to infection".

Biopsy of the observed large, bulging *epidural veins* in operated cases of amyotrophic lateral sclerosis showed "inflammatory tissue, polymorphonuclear infiltration and thrombophlebitis" (TEMPLE FAY[16] 1942).

Consequently, as briefly summarized in the present paper the hindrance of an adequate arterial blood supply to the spinal cord and brain stem caused by spondylosis, disc protrusions and root-sleeve fibrosis, might, *per se*, be elicited by a wide variety of injurious factors of i. a. traumatic, toxic and infectious origin.

CONCLUSIONS

The question is raised if it is possible to produce the picture of amyotrophic lateral sclerosis in experimental animals.

The answer is given that earlier experimental work gives evidence to the fact that pathologic changes identic with the picture of amyotrophic lateral sclerosis can be provoked by a slowly induced chronic hypoxemia of the spinal cord and brainstem.

The following opinion of the pathogenesis of amyotrophic lateral sclerosis is forwarded. Disc protrusions or spondylosis with osteophytes might narrow the adjacent intervertebral foramina. Especially the root-sleeve fibrosis produces a slowly developing partial compression of the corresponding *radicular artery* during its passage through the intervertebral foramen. This in turn induces a local chronic hypoxemia of the spinal cord with subsequent degenerative changes of the motor cells of the anterior horns (progressive muscular atrophy) and demyelination of the pyramidal tracts (symptoms of spasticity depending on the site of the lesion).

A cervical disc protruding laterally gives a condition of chronic compression of the *vertebral artery* during its passage through the vertebral canal and consequently a deficient arterial blood supply to the motor nuclei of the medulla oblongata (progressive bulbar paralysis).

The pathogenesis of the spinal cord lesions in amyotrophic lateral sclerosis viewed as a disturbance of the arterial blood supply of varying radicular arteries seems to be in accordance with a histopathologic observation made in 1925 by BERTRAND and van BOGAERT[6] that the pyramidal tracts often are fragmentarily affected with an almost total integrity at certain levels.

The *therapy* of amyotrophic lateral sclerosis has been a most gloomy subject and not one cure has been reported. The fatal progress of the cases seems to be inevitable.

In accordance with the above outlined pathogenesis of amyotrophic lateral sclerosis I have tried to improve the blood-circulation of the spinal cord and brain stem by treatment with vasodilating drugs and anticoagulants, i. a. intravenous application of heparine. It did not give any success, as might be presumed, because there exists probably a mechanical external compression of the radicular arteries by protruding discs and root-sleeve fibrosis.

In these hopeless cases, therefore, we have nothing to loose by surgical procedures with the purpose of making a decompression of the arteries compressed by disc protrusions and root-sleeve fibrosis.

If suitable surgical conditions should be present it is advisable to operate on cases of amyotrophic lateral sclerosis at a rather early stage before an irreversible strangulation of the radicular arteries has developed.

SUMMARY

Some pathological conditions of the spinal cord and brain stem induced by local hindrance of arterial blood supply are discussed.

The opinion is forwarded that the pathogenesis of the picture of amyotrophic lateral sclerosis may be a local chronic hypoxemia of the spinal cord and brain stem induced by very slowly progressive partial compression of radicular and vertebral arteries.

Decompression of the strangulated arteries by surgical intervention is therefore proposed.*)

*) In team-work with Dr. Tor Hiertonn at the Ortopedic Clinic, Karolinska Inst., Stockholm, surgical treatment of cases of amyotrophic lateral sclerosis has recently been started in June 1959.

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